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Chemical evolution of the Magellanic Clouds based on planetary nebulae

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Abstract. Planetary nebulae (PN) are an essential tool in the study of the chemical evolution of the Milky Way and galaxies of the Local Group, particularly the Magellanic Clouds. In this work, we present some recent results on the determination of chemical abundances from PN in the Large and Small Magellanic Clouds, and compare these results with data from our own Galaxy and other galaxies in the Local Group. As a result of our continuing long term program, we have a large database comprising about 300 objects for which reliable abundances of several elements from He to Ar have been obtained. Such data can be used to derive constraints to the nucleosynthesis processes in the progenitor stars in galaxies of different metallicities. We also investigate the time evolution of the oxygen abundances in the SMC by deriving the properties of the PN progenitor stars, which include their masses and ages. We have then obtained an age-metallicity relation taking into account both oxygen and [Fe/H] abundances. We show that these results have an important consequence on the star formation rate of the SMC, in particular by suggesting a star formation burst in the last 2-3 Gyr.

Keywords. planetary nebulae, abundances, chemical evolution

1. Introduction

Planetary nebulae (PN) are an essential tool in the study of the chemical evolution of the Milky Way and galaxies of the Local Group, particularly the Magellanic Clouds (see for example Maciel et al. 2006a, Richer & McCall 2006, Buzzoni et al. 2006, Ciardullo 2006). As the offspring of stars within a reasonably large mass bracket (0.8 to about 8 solar masses), PN encompass an equally large age spread, as well as different spatial and kinematic distributions. They usually present bright emission lines and can be easily distinguished from other emission line objects, so that their chemical composition and spatiokinematical properties are relatively well determined. In this work, we present some recent results on the determination of chemical abundances from PN in the Large and Small Magellanic Clouds, and compare these results with data from our own Galaxy and other galaxies in the Local Group. We also investigate the time evolution of the oxygen abundances in the SMC by deriving an age-metallicity relation for this object.

2. Abundances

Planetary nebulae and HII regions are particulary useful to study chemical abundances in the Galaxy as well as in other objects of the Local Group, especially since the advent of 4m class telescopes. While HII regions reflect the present chemical composition of the star-forming systems, PN can trace the time evolution of the abundances, especially when an effort is made to establish their age distribution (see for example Maciel et al. 2005). The elements S, Ar and Ne are probably not produced by the PN progenitor stars, as

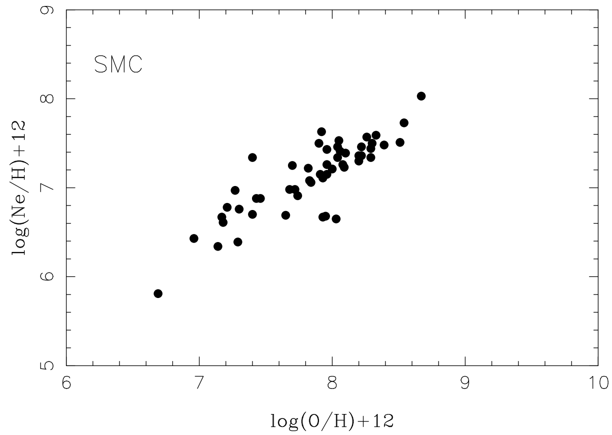

Figure 1. The Ne/H × O/H relation for the SMC.

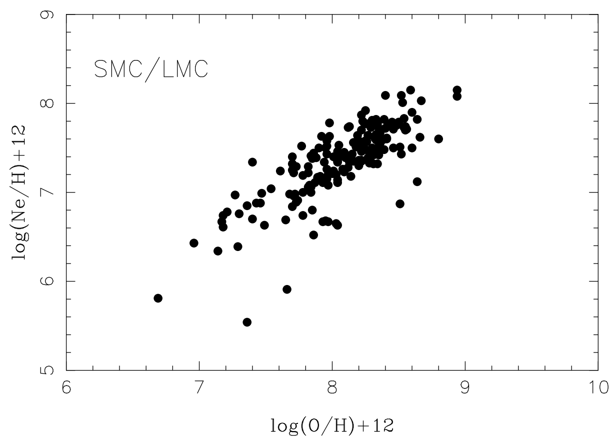

Figure 2. The Ne/H × O/H relation for the SMC and LMC.

they are manufactured in the late evolutionary stages of massive stars. Therefore, S, Ar and Ne abundances as measured in PN should reflect the interstellar composition at the time the progenitor stars were formed. Since in the interstellar medium of a star-forming galaxy such as the Milky Way and the Magellanic Clouds the production of O and Ne is believed to be dominated by type II supernovae, we may conclude that the original O and Ne abundances are not significantly modified by the stellar progenitors of bright PN, which makes them particularly useful for chemical evolution studies. An example is the determination of radial abundance gradients and their variations, which provide an essential constraint for chemical evolution models (cf. Maciel et al. 2005, Maciel et al. 2006b).

The variation of the ratios S/H, Ar/H and Ne/H with O/H show a good positive correlation for all studied systems in the Local Group, with similar slopes. The main differences lie in the average metallicity of the different galaxies, which can be inferred from the observed metallicity range. The galactic nebulae extend to higher metallicities [up to $\epsilon(\mathrm{O}) = \log \mathrm{O/H} + 12 = 9.2$], and the LMC objects reach $\epsilon(\mathrm{O}) = 8.8$, while the lowest metallicities in the SMC are about $\epsilon(\mathrm{O}) = 7.0$. As an example, Fig. 1 shows the Ne/H ratio as a function of O/H for the SMC, while Fig. 2 includes the PN from the LMC as well. In these figures we include the combined samples by our group (cf. Idiart

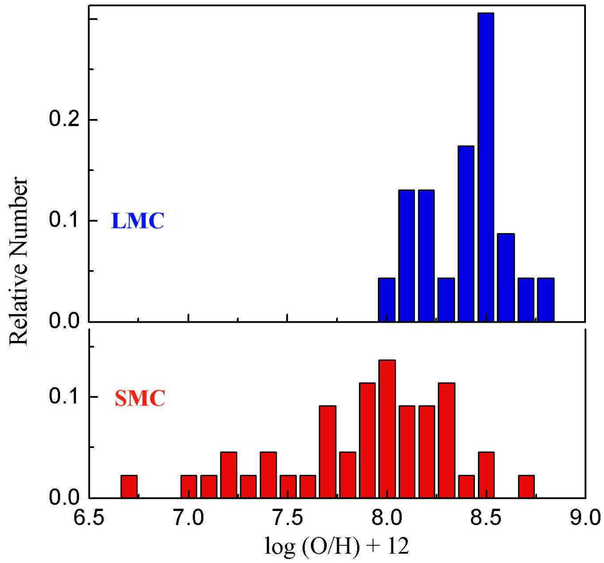

Figure 3. The metallicity distribution of PN in the Magellanic Clouds.

et al. 2007) and data from Stasińska et al. (1998) and Leisy & Dennefeld (2006). These figures can be compared with Local Group galaxies from Richer & McCall (2006). Other populations in the Galaxy also have a similar behaviour, as can be seen from the work of Escudero et al. (2004) for PN in the galactic bulge and Costa et al. (2004) for the disk.

PN are also extremely useful to determine the metallicity distribution in a given system, as accurate abundances of O, S, Ne, Ar and S are often measured. A comparison of the distribution in different systems can be used to infer their average metallicities, with consequences on the star formation rates. As an example, Fig. 3 shows the O/H distribution in the Magellanic Clouds, which can be compared with similar data for the galactic bulge and disk, such as given by Cuisinier et al. (2000). The metallicity distribution of PN in the galactic bulge can be used as an important tool in order to constrain galactic chemical evolution models, as shown by Maciel (1999).

3. Chemical evolution of the SMC

We investigated the chemical evolution of the Small Magellanic Cloud (SMC) based on abundance data of planetary nebulae (for details see Idiart et al. 2007). The main goal is to study the time evolution of the oxygen abundance in this galaxy by deriving an age-metallicity relation, which is of fundamental importance as an observational constraint for chemical evolution models of the SMC. We have used high quality PN data to derive the properties of the progenitor stars, so that the stellar ages could be estimated, using theoretical evolutionary tracks from Vassiliadis & Wood (1992). We collected a large number of measured spectral fluxes for each nebula and derived accurate physical parameters (effective temperatures, luminosities, masses and ages) and nebular abundances. New spectral data for a sample of PN in the SMC were obtained between 1999 and 2002, based on observations secured at the ESO-La Silla 1.52m and LNA-Brazil 1.6m telescopes. These data are used with data available in the literature to improve the accuracy of the fluxes for each spectral line. We obtained accurate chemical abundances for about 44 PN in the SMC. Our derived oxygen-versus-age diagram is shown in Fig. 4. A similar relation involving the [Fe/H] metallicity was derived on the basis of a correla-

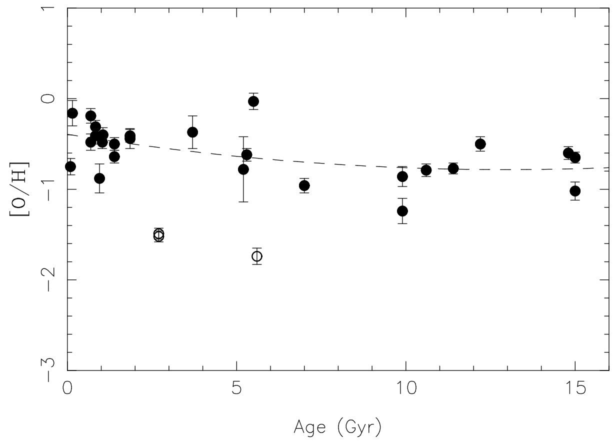

Figure 4. The age-metallicity of the SMC as derived from the O/H abundances. The steep increase in the metallicity near 2 Gyr is in good agreement with the the star formation burst as predicted by models by Pagel & Tautvaišiene (1998).

tion with stellar data. We have obtained the converted [Fe/H] metallicities by calibrating an [O/H] $\times$ [Fe/H] relationship matching the abundances of the youngest objects in our sample according to the models by Pagel & Tautvaišiene (1998). Taking into account the implications of the derived age-metallicity relation for the SMC formation, we suggest a star formation burst in the last 2–3 Gyr which is also apparent from Fig. 4. This behaviour is in agreement with some recent results based on stellar clusters and data on field stars (cf. E. Grebel, these proceedings), according to which there is no smooth age-metallicity relation for the SMC, at least during the last few Gyr.

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